Abstract

The work presented in the thesis focuses on systematically documenting the multiscale nature of the temporal persistence and spatial coherence of tropical rainfall. There are three parts to the thesis: The first two parts utilise satellite-retrieved rainfall at multiple observational resolutions to characterise the space-time organisation of rain; the third part assesses the ability of state-of-the-art coupled models to reproduce some of the observed features.

In the first part of the study, which focuses on the temporal persistence of rain, we analyze the Tropical Rainfall Measurement Mission (TRMM) satellite-based observations to compare and contrast wet and dry spell characteristics over the tropics (30°S-30°N). Defining a wet (dry) spell as the number of consecutive rainy (nonrainy) days, we find that the distributions of wet spells (independent of spatial resolution) exhibit universality in the following sense. While both ocean and land regions with high seasonal rainfall accumulation (humid regions) show a predominance of 2-4 day wet spells, those regions with low seasonal rainfall accumulation (arid regions) exhibit a wet spell duration distribution that is essentially exponential in nature, with a peak at 1 day. The behaviour that we observed for wet spells is reversed for dry spell distributions. The total rainfall accumulated in each wet spell has also been analyzed, and we find that the major contribution to seasonal rainfall for arid regions comes from very short length wet spells; however, for humid regions, this contribution comes from wet spells of duration as long as 30 days. An exhaustive sensitivity study of factors that can potentially affect the wet and dry spell characteristics (e.g., resolution) shows that our findings are robust. We also explore the role of chance in determining the 2-4 day mode, as well as the inuence of organized convection in separating reality from chance.

The second part deals with the spatial coherence of tropical rain. We take two different approaches, namely, a global and local view. The global view attempts to quantify the conventional view of rain, i.e., the dominance of the intertropical convergence zone (ITCZ), while the local view tries to answer the question: if it rains, how far is the influence felt in zonal and meridional directions? In both approaches, the classical e-folding length for spatial decorrelation is used as a measure of spatial coherence. The major finding in the global view approach is that, at short timescales of accumulation (daily to pentad to even monthly), rain over the Equator shows the most dominant zonal scale. It is only at larger timescales of accumulation (seasonal or annual) that the dominance of ITCZ around 7°N is evident. In addition, we also find a semi-log linearity between the spatial scales, seen from afar, and timescale of accumulation, with a break in linearity around typical synoptic timescales of 5-10 days. The local view quantifies the dominance of the zonal scale in the tropical ocean convergence zones, with an anisotropy value (ratio of zonal to meridional scales) of 3-4. Over land, on the other hand, the zonal and meridional scales are comparable in magnitude, suggesting that rain tends to be mostly isotropic over continental regions. This latter finding holds true, irrespective of the spatial and temporal resolutions at which rain is observed. Interestingly, the anisotropy over ocean, while invariant with spatial resolution, is found to be a function of temporal resolution: from a value of 3-4 at daily timescale, it decreases to around 1.5 at 3-hourly resolution, suggesting that perhaps rain fundamentally might be isotropic in nature at an event scale.

The final part analyses a few models from the suite of Coupled Model Intercomparison Project (CMIP5) models, to evaluate their ability to reproduce some of these aforementioned features. For all the strong biases that models are known to have, some of the observed features are captured well by the models. Specifically, on the temporal persistence front, the observed 2-4 day mode of wet (dry) spells of rain over humid (arid) regions is also seen in models. The overestimation of longer duration wet spells appears to be the primary cause of a positive bias in the number of rainy days from the models. In general, the tendency of models to not stop raining results in lower and higher number of shorter and longer duration wet spells, respectively, and consequently an overall reduction in dry spells of all durations. On the spatial coherence front, the main finding from the global view approach is that the observed semi-log linearity of the zonal spatial scale of rainfall as a function of timescale of accumulation is strikingly well-reproduced by the models. Even more remarkable is that the models are able to mimic the break in this linearity around 5 days (typical synoptic scale). What the models fail to do prominently is the transition of the dominance of equatorial rain at smaller timescales of accumulation to the dominance of ITCZ at around 7°N at higher timescales of accumulation. Based on the local view approach, we find that, in general, even though the zonal and meridional scales are overestimated, the observed isotropy of continental rain is captured very well by the models. Over the oceans, the success is less prominent, especially with the core of the ITCZ showing much larger ratios than those observed. Thus, the models seem to be able to reproduce the anisotropy for the wrong reasons, and the proposed anisotropy ratio could be a useful metric in further diagnosis of climate models.